REMOTELY PILOTED AIRCRAFT (RPA)
PERFORMING THE AIRDROP MISSION

GRADUATE RESEARCH PAPER

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Abstract

This research, sponsored by AMC/AA9, utilized a four round Policy Delphi Study to determine the potential utility, benefits, drawbacks and pitfalls of utilizing RPA to perform the airdrop mission. To scope the research to the near-term and ensure feasibility in a constrained budgetary environment, the study was restricted to the most capable current generation RPA, the MQ-9 Reaper, which is uniquely qualified from a cost, capability and availability standpoint to support current and emerging roles simultaneously. Literature concerning the MQ-9 Reaper, RPA development, Joint Precision Aerial Delivery Systems (JPADS), repurposing and rebranding, and Delphi Studies was reviewed.

The panel developed many innovative capabilities and benefits as well as insightful drawbacks and pitfalls. The panel's responses indicate that MQ-9 RPA capabilities should be developed both to support manned airdrop for large resupply missions and to conduct small, especially persistent, resupply missions autonomously. RPA airdrop development will greatly increase Unified Combatant Commanders' freedom of action in elevated or denied threat areas, as well as nuclear, biological, chemical or radiological environments, by removing the risk of loss of manned aircraft or harm to crews. The ultimate measure of the utility of MQ-9 RPA airdrop will be the increased effectiveness and efficiency of current airdrop missions and the development of new airdrop missions without negatively impacting current MQ-9 mission sets.

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Introduction

This study was inspired through conversations by the researcher with then Unites States Air Force (USAF) Air Mobility Command (AMC) Commander, General Duncan J. McNabb, in 2006 and 2007, regarding an unfilled need for persistent, on-call, precision airdrop. The need had been highlighted multiple times in Operation ENDURING FREEDOM (OEF) in Afghanistan, most memorably when a four man Navy SEAL element was attacked in 2005 by a force of approximately 100 enemy combatants and recorded in "Lone Survivor: The Eyewitness Account of Operation Redwing and the Lost Heroes of Seal Team 10" (Luttrell & Robinson, 2007). After a grueling firefight, there was only one team member left alive. As a light, mobile ground team, there was a lack of heavy weapons and medical equipment present. If that equipment had been available overhead, able to be called in on short notice, perhaps more than one member of the team would have survived.

The reason the Air Force was unable to provide persistent airdrop support to the ground forces was simply a matter of available assets, not technology. Regular USAF units do not have small, airdrop capable assets and it would be extremely inefficient to keep 24-hour orbits over battlefields with C-130s or C-17s for the relatively rare occasion where on-call airdrop would be the difference between life and death. Although it appears likely that the Air Force will acquire a small tactical airlift aircraft that could be airdrop capable, it would still be extremely costly, both in consumables and aircrew required, to maintain dedicated 24-hour orbits with a manned aircraft. Moreover, these platforms would not be able to support ground teams operating beneath elevated threat environments or denied airspace.

In such a hostile environment, ground teams would be unable to be resupplied from the air using conventional manned airdrop assets due to the threat level. This limitation likely enters into Unified Combatant Commanders' (UCC) calculus when deciding what, if any, forces to employ, overtly or covertly, under hostile airspace. The ability to achieve resupply with RPA would certainly alleviate if not eliminate this consideration for the UCCs, as historically the American public has shown little concern when faced with loss of RPA, versus grave concern over the loss of manned aircraft.

After several years of conversations between the researcher and his colleagues regarding how to create a persistent airdrop capability, the idea of utilizing RPA for airdrop began to percolate. Over time and with background research, it became increasingly likely to the researcher that this was a possible way to get everything desired by General McNabb regarding persistent, on-call precision airdrop for a very low cost, either monetarily or with regards to impact on other mission sets. In discussions with AMC/AA9, further possible uses arose and it became clear that RPA Airdrop could be useful far beyond the niche mission originally conceived by the researcher. Scenarios such as re-integrating into military service the low-cost, low-altitude airdrop to forward operating bases currently performed by contractors and utilizing dedicated airdrop RPA began to emerge, achieving both increased efficiency and effectiveness.

In order to scope the research and make it feasible in a constrained budgetary environment, this study is bounded within the context of the General Atomics MQ-9 Reaper RPA with only slight modifications. This decision also limits the scope to the near future while providing a ready vehicle for rapid prototyping, testing and employment; should decision makers decide to pursue the concept. This research seeks to identify the benefits and drawbacks as well as the feasibility of RPA airdrop within the narrow focus of the best-suited current-generation RPA, the MQ-9; which is uniquely qualified from a cost, capability and availability standpoint to support new and current roles simultaneously.

Researcher's Background

The researcher was a C-17A Globemaster III Pilot from 2001-2010, most recently serving in the role of an Evaluator Aircraft Commander at the Formal Training Unit. The researcher performed, instructed and evaluated hundreds of conventional and special operations low-level training airdrops between 2002 and 2010 as well as executing emergency combat airdrops at low and medium altitudes to 10 drop zones in Afghanistan in 2006. The researcher's aircraft sustained combat damage on one of the airdrops and, as a result, forums with the AMC/CC occurred, which initiated the researcher's interest in this area.

Current Situation

Currently, the United States Air Force does not use RPA operationally for airdrop missions. Airdrop missions currently consist of four main types, with multiple means of employment. The first three types of airdrop are usually performed by a C-130 or C-17. The first is personnel airdrop, either static line or freefall and is not being considered with RPA. Heavy equipment airdrop is the second main type and is used for, as the name implies, large payloads, including vehicles and is beyond the capabilities of the MQ-9 Reaper. The third type of airdrop is containers and approaches the capabilities of the MQ-9. Containers are typically 48 inches per side, 48 to 72 inches high and typically weigh from 1,000 to 3,000 thousand pounds and can dropped from altitudes ranging from 350 feet to above 25,000 feet. The system used to deliver the containers, or "bundles" as they are commonly known, is referred to as the Container Delivery System (CDS). Colloquially, the terms container, bundle and CDS are used interchangeably in the field. The final type of airdrop can, theoretically, be airdropped from any platform and is currently contracted out to light civilian aircraft in Afghanistan. It is Low-Cost, Low-Altitude (LCLA) airdrop. Rather than exiting the aircraft on rollers through an onboard system like heavy equipment or CDS, LCLA simply consists of a loadmaster pushing the bundles out the back or side door of the aircraft. Weights are typically less than 2,000 pounds and are frequently in the multi-hundred pound range, perfect for the MQ-9.

Several developments have led to an increase in accuracy for CDS airdrop since the beginning of OEF. The first was the development of the Joint Precision Aerial Delivery System (JPADS). JPADS is the integration of the U.S. Army's parachutes and guidance systems with the U.S. Air Force's in-aircraft laptop computer, communications receivers, Global Positioning System (GPS) receiver, GPS re-transmitter and small, light-weight dropsondes. A dropsonde is dropped from the aircraft during a pass over the drop zone (DZ) and sends back wind and temperature data to the aircraft on its descent. This data is then used by the operator of the in-aircraft laptop to determine the best release position for the JPADS bundle on a subsequent pass.

Prior to the dropsonde and in-aircraft computer utilized by JPADS, aircrew only knew winds at the surface and winds at altitude and utilized a simple average wind speed to calculate a release position. This inaccurate modeling caused a need for low altitude drops to ensure accuracy. After experience with the dropsonde data for JPADS, the idea was extended to unguided parachutes as well. In this instance, the dropsonde data is used to calculate a release position just as with JPADS, the only difference being that the load cannot steer itself, preventing advanced techniques like standoff airdrop or the ability to obtain pinpoint accuracy. This technology has greatly increased the altitude that an aircraft can drop from while maintaining an acceptable level of accuracy. There are, therefore, now three methods of performing CDS airdrop; those being the traditional method with simple average winds, which is insufficient for high accuracy from high altitudes; utilizing a dropsonde with unguided parachutes, called Improved CDS or ICDS which is sufficient for many missions; or JPADS, which is extremely accurate and allows for standoff airdrops (Benney et al., 2007). Unfortunately, both ICDS and JPADS require the aircraft to fly over the drop zone twice, once to drop the sonde and again to drop the bundles. This would be unacceptable in certain elevated threat environments as the enemy would be alerted to the aircraft's presence on the dropsonde pass and could engage it on the actual airdrop pass. It would be possible, however, to utilize an RPA outfitted with a dropsonde dispenser to gather the data without alerting the enemy, providing a manned aircraft with the increased accuracy required for JPADS or ICDS without betraying the element of surprise (Wuest & Benney, 2005).

Literature Review

This literature review provides a background for the technical and theoretical underpinnings of repurposing the MQ-9 Reaper to perform airdrop. The review focuses on three main areas. First, the technical aspects of the MQ-9 and various existing JPADS are explored in order to provide a quantitative foundation for the feasibility of the research. Next, historical, current and future RPA capabilities are reviewed to provide a context for the rapid advancement in the field and the ability of the industry to rapidly respond to warfighter requirements. Finally, business literature relating to repurposing and remarketing existing products is discussed to frame ways in which the transition could be enabled to occur with minimum disruption to current mission sets.

MQ-9 Reaper Technical Review

This is a critical time in the development of roles and missions for RPA. In certain areas, such as intelligence, surveillance and reconnaissance, the mission has already reached a functional level of maturation. In other areas, such as time sensitive targeting for kinetic engagement, the mission is still maturing both in the laboratory and on the battlefield (Bolkcom, 2008). However, in many other cases, such as long range strike, aerial combat, and transportation, the roles for RPA have not yet been fully identified, let alone defined (Geer & Bolkcom, 2005).

The General Atomics MQ-9 Reaper is currently the most capable multi-role RPA in the USAF inventory. There are 47 MQ-9s in the active Air Force fleet with one in the Air National Guard and the Air Force request for the 2011 budget was an additional 48, doubling the fleet in just one year (Lyle, 2010). The MQ-9 currently performs Intelligence, Surveillance and Reconnaissance (ISR) (specifically Signals Intelligence (SIGINT) and Full Motion Video (FMV)), Close Air Support (CAS) and Air Interdiction (AI) missions. To accomplish these missions, the MQ-9 was designed to have an extremely high endurance of 30+ hours. This endurance was enabled through a combination of a high wingspan to fuselage ratio of 66 feet to 36 feet, a fairly low fully loaded and fueled maximum takeoff weight of 10,000 pounds, versus 585,000 pounds for a C-17 and 175,000 pounds for a C-130J, and a turboprop engine designed for a maximum speed of 240 knots (General Atomics Aeronautical, n.d.). The maximum 900 horsepower engine is able to operate with reduced fuel consumption when propelling the aircraft at its normal cruise speed of 200 knots. The Reaper is also relatively affordable, with a unit cost of approximately $13 million which compares favorably to the $48.5 million per copy for the C-130J (United States Air Force, 2009b) and the $202 million per unit for the C-17. The empty weight of the MQ-9 is 4,900 pounds, with a maximum fuel capacity of 4,000 pounds over a range of 1,000 nautical miles. This leaves 1,100 pounds of payload capacity available on every sortie. If fuel is reduced, maximum payload can be increased to 3,750 pounds with 750 pounds of internal stores and 3,000 pounds of external stores loaded on up to seven hardpoints (General Atomics Aeronautical, n.d.; United States Air Force, 2010b).

The MQ-9 was chosen as the focus for this study over the other major Air Force RPA, the MQ-1B Predator or the RQ-4 Global Hawk, due to multiple factors including cost, payload, availability, and typical mission set. The MQ-9's capabilities compare very favorably to the MQ-1B, the most prevalent fielded RPA with 138 in the USAF, for the purpose of airdropping bundles in the several hundred pound range. The MQ-1B was designed initially to solely provide ISR as the RQ-1 and therefore has a very low available payload. The Predator has a maximum payload of just 450 pounds and its 115 horsepower engine only allows speeds of 100 knots, with a normal cruise speed of only 70 knots and range of 675 nautical miles. It has been modified to carry two small air-to-ground AGM-114 Hellfire missiles, but they easily consume all available payload on the MQ-1B (United States Air Force, 2010a). While the Predator is well suited to robust ISR and limited CAS and AI duties, the MQ-9's additional payload and speed make it far more applicable to the airdrop mission. The RQ-4, alternately, was designed as a higher altitude, longer endurance aircraft than the MQ-9, flying at 65,000 feet with a range of 8,700 nautical miles, propelled at 310 knots by its turbofan engine. Designed as a replacement for the venerable U-2 manned ISR platform, it is not intended to carry a payload. As a result, even though it is a larger aircraft, its maximum payload is lower than the MQ-9 and it has a five times greater unit cost of approximately $65 million. As a result of the significant cost, the USAF currently only has 7 RQ-4A and 3 RQ-4B aircraft (United States Air Force, 2009c), so the number of Global Hawks is not sufficient to achieve persistent coverage over multiple areas and its high operating altitude could be problematic for airdrop.

JPADS Technical Review

While the decision to utilize the MQ-9 as a baseline for investigation into the possibility of RPA airdrop utilizing existing systems is well supported by the above considerations, the case for which specific JPADS to use is less clear and was therefore not constrained as part of this study. JPADS is a technology which is still undergoing much innovation, not having first been fielded until 2004 in an interim capacity. The systems all have certain elements in common. They combine a steerable parafoil or canopy with an airborne GPS-based guidance, navigation and control unit (AGU) and electro-mechanical steering actuators. Prior to deployment, the control unit interfaces with the mission planning tool for weather data assimilation and airdrop mission planning data, such as the desired flight path and coordinates for the desired point of impact (PI) on the DZ. JPADS capacities defined by the Department of Defense (DoD) range significantly in capacity from 500 pounds to 60,000 pounds. For this research, we are concerned with the extra light JPADS versions, known as JPADS-XL. These systems have a defined payload range of 500 pounds to 2,200 pounds and were designed specifically for the use envisioned by the researcher; to enable special operations forces (SOF) and small ground team resupply (U.S. Army NSRDEC Warfighter Protection and Aerial Delivery Directorate, n.d.). In addition, many companies are also developing lower weight capabilities which would likely be more appropriate for RPA airdrop.

An example of this is the Onyx family of systems, being developed by Atair Aerospace. The company was awarded a contract to develop Onyx in the XL category with a weight capability from 500-2,200 pounds known as Onyx 2200 ("Onyx," 2007). Concurrently, Atair Aerospace has developed the Onyx Micro Light (ML) for payloads ranges of 10 to 150 pounds, Onyx 300 for payloads ranging from 0 to 300 pounds and the Onyx Ultra Light (UL) for a payload range of 250 to 700 pounds. The system utilizes a ram air canopy for the majority of their flight, followed by a round parachute in the terminal phase of flight for landing. In addition to having the correct weight requirements for the types of RPA airdrop being explored in this research, the Onyx system is already imbued with significant advanced technology. The Onyx have the ability to correct for damage to the load or canopy through the control unit and can follow programmed routes in formation while communicating with each other to prevent collisions in the case of deployment of multiple bundles simultaneously (Atair Aerospace, 2010).

Other possible JPADS for consideration include the Capewell Components, Inc. and Vertigo, Inc. Affordable Guided Airdrop System (AGAS), which can support payload weights from 200 to 10,000 pounds (Jorgensen & Hickey, 2005); the Mist Mobility Integrated System Technology, Inc. Sherpa family, with available payloads between 100 and 10,000 pounds (MMIST, n.d.); the Strong Enterprises Screamer 2.2k, with a weight range from 500 to 2,200 pounds; the Dutch Space (in partnership with the National Aerospace Laboratory (NLR) of Amsterdam) Small Parafoil Autonomous Delivery System (SPADES), with a payload capacity of 220-440 pounds or 265-551 pounds, depending on the parafoil used; (Benney et al., 2007) and the Airborne Systems Microfly and Dragonfly, with capacities of 100-700 pounds and 700-2,200 pounds, respectively (Airborne Systems, 2010b; Airborne Systems, 2010a).

The various JPADS have many characteristics in common, but various levels of AGU sophistication and parachutes types are represented. The most basic and oldest system is the AGAS, which utilizes round parachutes for all phases of flight, limiting standoff range. The

Screamer and Onyx systems utilize round parachutes for the terminal phase of flight, which could degrade accuracy and prevent a soft landing flare that is achievable with a parafoil. The SPADES weighs only 35 pounds, can be fitted with an airborne guidance unit enabling two-way communication with a ground team and remote control during descent and is able to detect winds during descent, thereby mitigating the need for a dropsonde pass prior to employment. Finally, the Sherpa system utilizes a parafoil until landing for improved accuracy and reduced impact velocity, can follow programmed waypoints to its destination to avoid threats or detection and can be re-programmed in flight through a GPS equipped ground control unit (MMIST, n.d.).

The extensive breadth of JPADS manufacturers and capabilities indicates that systems are already available which meet the requirements of light weight and high accuracy for RPA airdrop using existing commercial-off-the-shelf (COTS) technology. Given the differences, however, a careful selection process would be required to ensure that the system which best balances the compromises between payload weight, system weight, accuracy, survivability, Command, Control and Communications (C3), logistics support and price is selected.

Modern History of RPA Development

The modern age of RPA began with the General Atomics RQ-1 Predator in 1996. The aircraft was initially designed as an ISR platform only, with an endurance of up to 40 hours (General Atomics Aeronautical, 2011), range of 675 nautical miles and payload capability of 450 pounds being propelled at just 70 knots with its 115 horsepower engine. However, it initially was not designed to carry an expendable payload. Over time, it became apparent that many targets were identified by the Predator's ISR capabilities that could not be engaged by other platforms in a timely manner. Therefore, in 2002, the Predator began receiving a retrofit including the addition of hardware and software to achieve the capability of striking time-sensitive targets with AGM-114 Hellfire Missiles and was re-designated the MQ-1 (United States Air Force, 2010a). This repurposing program has been highly successful with hundreds of targets believed to have been serviced to date (Bergen & Tiedemann, 2010).

Following the success of the MQ-1 Predator, General Atomics developed the MQ-9 Reaper. The Reaper, unlike the Predator, was designed specifically to carry a significant expendable payload to perform the hunter-killer mission. This has resulted in a 733% increase in payload, 210% maximum speed increase and a range increase of 48% over the MQ-1. As a tradeoff for the increased performance, however, sortie duration has been reduced by 25% to 30 hours (General Atomics Aeronautical, 2011). The ISR capabilities of the Reaper are about to expand dramatically as it is equipped with "Gorgon Stare" RTV pods that will enable feeds of 10 different locations to be streamed to 10 different users simultaneously. Six first-generation pods are expected to be delivered in 2011 along with three second-generation pods, capable of 30 feeds each, increasing theoretical fleet-wide Reaper RTV capability to 189 feeds from the current 48. The third-generation pods will be able to stream 65 feeds each, exponentially increasing the RTV performance of the Reaper fleet, perhaps mitigating the loss of ISR capacity that would occur by adding mission sets such as airdrop (Tirpak, 2010).

Separately from the tactically and occasionally operationally focused MQ-1 and MQ-9, Northrop Grumman developed the strategically aligned RQ-4 Global Hawk in the late 1990s. The Global Hawk was developed as a high-altitude, long-range and long-duration ISR platform, operating at altitudes up to 65,000 feet with a loiter speed of 310 knots, up to 35 hours endurance and a range of 12,300 nautical miles (Northrop Grumman, n.d.). Based on the specifications, the

RQ-4 is clearly more of an inter-theater asset than the MQ-1 or MQ-9 which, based on their low airspeeds, are limited to intra-theater operations.

The newest acknowledged operational RPA is the RQ-170 Sentinel. This aircraft is clearly of a different generation than the utilitarian first (modern) generation designs of the MQ-1, RQ-4 and MQ-9. The RQ-170 is a Lockheed Martin designed flying wing with some stealthy characteristics and a wingspan of approximately 65 feet. The platform is, at present, believed to be used solely for ISR missions (Fulghum & Sweetman, 2009). It is, however, likely the first of the second-generation RPA to see operational use. Given the lack of publically available information about the RQ-170 combined with the history of the RQ-1 gaining a CAS role and becoming the MQ-1, it is also quite possible that it is performing, or may someday perform, missions in addition to ISR.

For the Air Force, the future beyond the RQ-170 is broadly envisioned in the *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047* (United States Air Force, 2009a). The plan envisions families of RPA ranging from insect-sized, hand launched platforms to large RPA equivalent in size to our current airlift, tanker and bomber aircraft. RPA are expected to pass through three more generations over the course of the next 36 years, with each generation gaining more capability, modularity and autonomy. The fourth-generation RPA (2040 time-frame) are currently envisioned to have a fully modular payload and avionics architecture, designed to allow sharing of a common airframe for cost savings while greatly increasing supported mission types. For comparison, the MQ-9, the most capable current-generation medium RPA, currently provides just CAS, AI, SIGINT and FMV. It is envisioned that the proposed common medium RPA airframe (MQ-Mc) will be capable of performing electronic warfare (EW), Suppression of Enemy Air Defenses (SEAD), connectivity, information integration, collection, CAS, air interdiction, advanced ISR, air refueling, aeromedical evacuation, personnel recovery, counter air, missile defense and strategic attack missions (United States Air Force, 2009a). The large version future RPA (MQ-Lc) is forecast to provide "air mobility, airlift, air refueling, EW, multi-(intelligence) ISR, strategic attack, global strike, CAS, air interdiction and humanitarian assistance operations" (United States Air Force, 2009a, p. 40).

In view of the current state of RPA employment, contrasted against current developments within industry and the official Air Force Unmanned Aircraft Systems "Flight Plan", it is clear that even today we are in a nascent state of capabilities. The long term goal, assuming public policy supports it, is to develop fully autonomous RPA. This would include "auto air refueling, automated maintenance, automatic target engagement, hypersonic flight, and swarming… The end result would be a revolution in the roles of humans in air warfare" (United States Air Force, 2009a, p. 50). Given these lofty goals, RPA airdrop would appear to be a relatively simple addition to the planned mission sets, but one that has largely been overlooked to date, as logistics functions often are.

Repurposing and rebranding existing products

There are a significant number of considerations that must be addressed both before and during the repurposing or rebranding of existing products. Repurposing and rebranding is applied across spectrums, from ethereal philosophical considerations of how one listens to music differently since the introduction of a shuffle feature on portable music players (Burton, 2009) to repurposing and rebranding the entire city of Detroit (Berkooz, 2010). Within this vast spectrum also exist the digital mediums, which in some cases can be repurposed and rebranded without significant capital expenditure beyond the time of the programmer (Korthaus & Barros, 2009).

At the higher end of required capital and time investment, there is a movement to convert suburban "McMansions" abandoned during the US recession of 2007-2009 into communal living spaces accommodating seniors, families and young professionals, providing mutual support within the same building, thus dually relieving the burden on society of vacant homes and increasing community ties in a highly mobile age (McGrew, 2008).

The most commonly cited instances of repurposing and rebranding within scientific literature come from the pharmaceutical industry. The pharmaceutical industry views repurposing and rebranding as a critical and methodical component of their business, rather than the more isolated or opportune approaches that appear in literature from other industries. As an indication of the gravity with which this discipline is pursued, there are currently biotechnology companies whose primary focus is indentifying ways to repurpose and rebrand existing compounds (Grau & Serbedzija, 2005). Others propose utilizing the already established safety monitoring schemes, known as pharmacovigilance, to identify unexpected results and target repurposing research (Boguski, Mahdi, & Sukhatme, 2009). This robust framework provides ample credibility to the potential effectiveness achievable through repurposing and rebranding.

Perhaps the most appropriate precedents come from within the security and defense industries themselves. The security industry shifted rapidly after the attacks of 11 September, 2001, repurposing seaborne and port monitoring products and services that had previously been used in non-security roles, but which had applicability to homeland security (Haveman & Shatz, 2006). There are innumerable examples of repurposing and rebranding within the defense industry. The most salient include the addition of a 20mm cannon to the F-4 Phantom II, after it was operational, based on feedback from pilots in combat; the introduction of up-armored HUMVEES in Iraq as the improvised explosive device threat matured; and the addition of weapons to the RQ-1 Predator. Repurposing the RQ-1 from an ISR platform to a CAS and AI platform and rebranding it the MQ-1 is a direct linkage to the scenario posited through this research; the repurposing of the MQ-9 to include the airdrop mission set.

For future RPA development of MQ-Ma, MQ-La and beyond, some of the most useful ideas and terminology come from an unlikely source. In an anthology of works on how technology is used in the publishing industry, author Vanessa Chan discusses multipurposing, rather than repurposing content (Chan, 2010). This is a distillation of the idea of considering many possible uses during the design or creation phase and ensuring that the finished product will be capable of being used in those formats. The author argues that this is distinct from repurposing, which is changing the product after a subsequent need has been identified. In application to RPA development, this would argue for designing families of platforms that incorporate not only the ability to perform all required known missions, but also thinking critically to determine and incorporate support for the self-reinforcing loop of new and expanded mission sets that will be created by new RPA technology and tactics.

Methodology

This study attempts to establish an initial position of a joint, cross-functional panel of experts regarding RPA airdrop. In order to conduct research focused on the near future and recognizing current budgetary challenges, the research was limited to the feasibility of utilizing the operational MQ-9 Reaper for airdrop. The four research questions asked were: “What are the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft?”, “What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?", "What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?", and "What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?" These questions will answer, with regards to airdrop, what missions the MQ-9 can perform, if it is advantageous over manned airdrop, unavoidable drawbacks compared to manned airdrop, and difficulties that will need to be addressed early to avoid future contingencies. The research methodology used to investigate these questions was a modified Delphi Study.

The data for this study were developed through a Delphi Study for policy development or Policy Delphi (Linstone & Turoff, 2002, pp. 71-72) conducted via e-mail. A Policy Delphi is appropriate for allowing "…a group of individuals, as a whole, to deal with a complex problem" (Linstone & Turoff, 2002, p. 3). Specifically, in this case, the Policy Delphi allows for determination of the positive and negative aspects of a policy decision regarding utilizing the MQ-9 for airdrop missions. This differs from a traditional Delphi Study that seeks agreement. In this case, it is assumed that a senior leader would not be interested in a group decision, "…but rather, have an informed group present all the options and supporting evidence for his(/her) consideration" (Linstone & Turoff, 2002, p. 80). This Policy Delphi also serves to bring together a diverse group of individuals with no history of interaction while mitigating the risk that group-think or a forceful personality could have on the results (Linstone & Turoff, 2002, p. 4). These benefits are achieved through the participants each interacting directly with the researcher via e-mail while being guaranteed confidentiality with regards to their identity. Recent research has also indicated that e-mail surveys produce slightly elevated response rates compared to traditional mail surveys and are consistent with regards to reliability (Griffis, Goldsby, & Cooper, 2003, p. 255).

The Policy Delphi is envisioned to have six phases, some of which operate concurrently, identified below (Linstone & Turoff, 2002, p. 84). If consensus is achieved at any time after phase three, the study would be concluded, otherwise the phases will continue through phase six, at which point the process will be exhausted regardless of agreement. The Delphi Rounds indicate surveys sent to the panel. Round 1 consists of the open ended questions identified above. Round 2 consists of lists of options developed through a content analysis of Round 1 responses and are rank ordered by the panel. Round 3 consists of the lists being returned in the rank order given by the panel with a request for reconsideration based on the consensus rank order. If the member disagrees with the consensus position or feels strongly about any position, expanded rationale is requested. Round 4, if needed, consists of the list being returned a final time, supported by panel members' key arguments for and against each item along with a final request for rank ordering (Ludlow, 2002, p. 115).

Table 1. Policy Delphi Phases

1) Formulation of the issues by the researcher
2) Determining the policy options available (Delphi Round 1)
3) Determining initial positions on the issues (Delphi Round 2)
4) Exploring reasons for disagreement with possible move to agreement (Delphi Round 3)
5) Evaluating the underlying rationale for rankings (Delphi Round 3)
6) Reevaluating the options (Delphi Round 3-4)

The research questions were developed by the researcher, in consultation with other airdrop subject matter experts, AFIT faculty and the research advisor. The questions attempt to encapsulate the questions that would be raised during the initial policy discussions at the general officer level in order to reduce the length of a future staffing process and improve the quality of responses by drawing on a diverse panel of experts while removing interpersonal dynamics.

Table 2. Research Questions

1) What are the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft?
2) What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?
3) What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?
4) What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?

Research Instrument

Literature was also reviewed regarding utilizing an embedded survey versus an attached file as the e-mail survey instrument. Although studies showed up to 75% lower response rates for attached surveys, one of the studies pointed out that "If it is known that the sampling frame consists mostly of people who are technologically sophisticated who would appreciate a professional-looking questionnaire, the attached e-mail survey could well be the best survey medium. As the technological sophistication of the online population grows, the attached e-mail survey will undoubtedly grow in popularity" (Dommeyer & Moriarty, 1999). Based on this research, combined with the fact that typical response rates for e-mail surveys are in the 40% range and the complexity and open-ended nature of the research, the decision was made to utilize an attached e-mail survey. The surveys are included in Appendices A-D.

Analysis: The Expert Panel

Round One

The research questions were sent to decision makers and experts in targeted positions throughout the DoD. Invitations to the panel members were coordinated with the sponsor of the research, Mr. Donald Anderson (USAF AMC/AA9), in an attempt to obtain a higher response rate based upon research indicating that pre-notification and official sponsorship increase response rates (Ladik, Carrillat, & Solomon, 2007).

The Delphi Survey target audience was made up of subject matter experts drawn from the intelligence, operations, logistics, communications, planning and analysis functions within the directly affected Air Force Major Commands (MAJCOMs), Army Material Command and the lead functional combatant command for airdrop. Specific Air Force and joint commands identified were Air Mobility Command, Air Combat Command, Air Force Special Operations Command and United States Transportation Command. Within these organizations, the A or J-2, 3, 4, 5, 6, 8, 9 and Chief Scientist (if one exists) were surveyed, along with the commanders and deputies of these commands. The MQ-9 Systems Project Office was also surveyed. In addition, an expert from the Army Logistics Innovation Agency and three experts from the Airdrop Technology Team, the Joint Precision Aerial Delivery Advanced Concept Technology Demonstration Team and the Aerial Delivery Engineering Support Team as well as the director of the Airdrop/Aerial Delivery Directorate of the US Army Natick Soldier Research, Development and Engineering Center were surveyed. This mixture yielded a target sample of 50 individuals.

Of the 50 individuals surveyed, only six initially completed the first round in the two weeks allocated. The researcher conducted two follow-up contacts at one week intervals and was able to achieve three additional responses for a total of nine or 18%, with the last being returned 32 days after initial contact. Response rates were even lower, just 5%, for the researcher's parent commands. This contrasts poorly with the typical response rate for surveys, determined through a recent meta-analysis of 490 studies, of 52.7% (standard deviation of +/-

20.4%) (Baruch & Holtom, 2008). Conversely, the response rates were extremely high (60%) for the Army individuals surveyed. Anecdotally, through conversations with both respondents and non-respondents, it appears as though the low response rates from fellow air mobility professionals was a result of “familiarity breeding contempt”, while the high response rates from individuals outside the air mobility ecosystem were due to having their opinion valued from a member of another community or service. Fortunately, the nine respondents covered all desired functional areas except for logistics, communications, analysis and senior level decision makers. There was expert representation from Air Mobility Command, Air Combat Command, Air Force Special Operations Command, the MQ-9 Systems Project Office, the Army Logistics Innovation Agency and the Airdrop/Aerial Delivery Directorate of the US Army Natick Soldier Research, Development and Engineering Center. These respondents’ backgrounds are indicated in the table below. The lower relative duration of RPA experience, when contrasted with airdrop experience, are due to the emerging nature of the mission. Within that context, the experience levels of the panel members capture a high percentage of modern RPA development.

Table 3. Expert Panel

Airdrop systems senior leader / engineer with 20+ years airdrop and 10+ years RPA experience
MAJCOM RPA operations expert with 20+ years airdrop and 3 years RPA experience
JPADS senior project manager / engineer with 20+ years airdrop and 5+ years RPA experience
MAJCOM intelligence expert with 15+ years intelligence and 5+ years RPA experience
Army logistics expert with 15+ years logistics experience at staff level
Medium RPA senior engineer with 10+ years in current position
MAJCOM airdrop operations expert with 10+ years airdrop experience
RPA instructor pilot with 1,200+ hours
MAJCOM RPA employment planner with 4 years RPA experience

As expected, based on previously conducted research, the length and volume of answers to the last question in round one were significantly less than on the first question (Galesic & Bosnjak, 2009). There were 51 responses to the first question, many full paragraphs long, while there were only 31 responses to the fourth question, many just short phrases, even though it was arguably a much more open-ended question. While this is unfortunate, the researcher believes that the order of the questions were appropriate in terms of presenting a logical flow to enable the holistic consideration of the overall problem by the panel.

Round Two

Once the responses to the initial round were returned by the respondents, the responses were distilled by a content analysis panel comprised of two researchers and two faculty members. The panel developed short phrases utilizing variable clustering and rank-ordered them from most to least commonly cited within each of the four question areas. This was a difficult process as the first question alone yielded 51 individual responses from the nine respondents. The literature is inconclusive on the effect of survey length on participation, with some arguing that increased length lowers participation and reduces quality (Newell, Rosenfeld, Harris, & Hindelang, 2004; Douglas, 1995) while others indicate no or minimal impact (Beebe et al., 2010; Hoerger, 2010). However, no literature was found which indicated that shortening the survey decreased participation. Given the low response rate to the first round, the researcher, along with the advisor, decided to limit the responses utilized for the second round to the minimal number possible without excessively compromising fidelity.

This was achieved through considerable encouragement from the advisor towards brevity, with the responses being consolidated into eight variable clusters for question one, eight for question two, nine for question three and 10 for question four. Additionally, the questions were modified slightly to accommodate the change from the open ended format of round one to the rank order format of round two. The respondents were then sent the lists, which were rank ordered unbeknownst to them based on frequency count from round one, and asked to rank order the responses in Attachment B. All nine respondents from the first round also participated in the second round. This was likely influenced by conducting personal appeals that were not possible in the first round due to not having individual contacts in all surveyed offices. Research indicates that this method significantly increases response rates (Heerwegh & Loosveldt, 2007).

Round Three

The data obtained through the second round was then compiled and analyzed utilizing Kendall's W Coefficient of Concordance (Okoli & Pawlowski, 2004, p. 22). The following formulas were utilized to determine the agreement represented by the rank order of the n topics by m participants within each question (Kendall & Smith, 1939). The rank order (1-10) is represented by *r*. First, the individual rank orders for a given topic are summed. Second, the mean of all of the ranks is calculated. Third, the sum of squares is calculated. Finally, Kendall's W is calculated. Literature suggests .7 as a threshold for significant agreement (Okoli & Pawlowski, 2004, p. 22).

Figure 1. Calculations required to determine Kendall's W (Kendall, 1939)

$$R_i = \sum_{p=1}^{m} r$$

$$\bar{R} = \frac{m(n+1)}{2}$$

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2$$

$$W = \frac{12S}{m^2(n^3 - n)}$$

Table 4. Kendall's *W* (Schmidt, 1997, p. 767)

.1	Very Weak Agreement
.3	Weak Agreement
.5	Moderate Agreement
.7	Strong Agreement
.9	Unusually Strong Agreement

The data received for round two showed little agreement amongst the panel, with Kendall's W scores of .095, .323, .271 and .102 for questions 1-4, respectively. This is not unexpected with such a diverse group representing different functional communities and different services. In addition, as noted above for a Policy Delphi, consensus is not the overriding concern, but simply a nicety if it is achieved after the desired exhaustive enumeration and consideration of policy options. As a result of the second round, the survey instrument for round three was re-ordered in the rank selected by the group and in this round, they were informed of that fact. The respondents were then asked to re-rank the topics within each question. In addition, the respondents were asked to expound on any rankings they disagreed with and changed or any rankings that they felt strongly about, even if they agreed, for use in round four.

The respondents re-ranked the questions slightly in round three, but only three of the nine respondents included the requested justifications in order to attempt to influence the panel in round four. Round three resulted in Kendall's W scores of .326, .410, .413 and .127 for questions 1-4, respectively. This showed increasing agreement and indicated that a fourth round could be productive with respect to increasing agreement.

Round Four

The third round results were utilized to produce a modified rank order for round four. In addition, the respondents were given unfiltered responses from the three panel members who provided inputs in round three regarding issues they felt strongly about. These responses are included below in the Delphi Panel Perspectives section. Questions were slightly re-ranked at the lower extreme by the panel, but no massive shifts were seen. Unexpectedly, Kendall's W scores exhibited movement lower as well as higher. Round four resulted in Kendall's W scores of .343, .271, .368 and .167 for questions 1-4, respectively. The panel achieved higher consensus on questions 1 and 4, but actually decreased in consensus on questions 2 and 3, with a marked decrease of .139 on question 2. Two additional panel members took the opportunity to provide inputs during this round for clarification of their positions which are included below.

Delphi Panel Perspectives

Questions 1-4

The panel introduced a great many ideas for consideration, oftentimes surprising the researcher, who had pondered the issue for years, with their innovation and insight. Nearly four times the number of considerations the researcher had thought of before the study were developed by the panel. These are reviewed below, by question and in order of frequency count from round one, with expansion on the topics from the responses, if desirable, without the need for truncation that was required for the survey rounds.

For the first question, "What are the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft?", responses were:

Table 5. Consolidated first round responses to question 1 for second round

Responses	**Rank Order 1-8**
Imagery & PI coordinate updates in dynamic environment	
DZ wind analysis	
Resupply of small units	
Airdrop of small items: i.e. ground sensors, robots, or Information Ops leaflets	
Drop Zone Control Officer (DZCO), C2, & manned aircraft communications relay	
Search & C2 in a Personnel Recovery (PR) with ability to re-supply the survivor(s)	
Enable remote DZCO operation with no control personnel on the ground	
Visual Guidance, Navigation & Control (GNC) for GPS denied airdrop	

The “Imagery & PI coordinate updates in dynamic environment” topic was comprised of several responses, indicating utilizing the AN/APY-8 Lynx Synthetic Aperture Radar (SAR) for imagery updates; obtaining high-fidelity DZ PI identification utilizing the AN/DAS-1A Multi-Spectral Optical Targeting System Targeting Pod (TGP); conducting pattern of life analysis and coherent change detection; detect, observe and identify personnel or equipment on the DZ; and generate new, precise PI coordinates if required in a dynamic environment with the TGP. “DZ wind analysis” was comprised of three main types of responses, those indicating the use of a look-down wind measuring system to profile winds to the surface; those proposing the use of dropsondes; and a suggestion to utilize onboard telemetry to determine altitude winds. Some of these responses indicated that the RPA could be utilized to support manned aircraft while others indicated it would be collecting winds in support of its own airdrop. The “Resupply of small units” topic included suggestions for both GPS guided and unguided airdrops as well as different types of loads. These included multiple suggestions for pre-configured airdrop bundles of specific types, such as medical, ammunition, batteries and heavy weapons. The remaining categories are self-explanatory and were comprised of less than three responses each, making the wording for the questionnaire able to more fully reflect the less aggregated inputs.

For the second question, “What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?”, responses were as follows:

Table 6. Consolidated first round responses to question 2 for second round

Responses	**Rank Order 1-8**
Mitigate risk to manned aircraft in elevated threat environments	
Provide persistent availability of emergency resupply on routine ISR missions	
Wind Analysis to eliminate current need for multiple passes by manned aircraft	
Airdrop of unattended ground sensors in real-time support of ISR missions	
Airdrop of Unmanned Ground Systems (UGSs) in elevated threat areas	
Nuclear, biological, chemical, radiological (NBCR) environment airdrop operations	
24/7/365 alert to launch for emergency airdrop missions	
Low-Cost, Low-Altitude airdrop	

The "Mitigate risk" category included both the reduction of risk for traditional combat operations as well as the opening of new battlespace to the UCCs by having a low risk means to resupply small teams operating covertly in hostile territory. The "Provide persistent availability" focused on the MQ-9 carrying two or three small, several hundred pound, JPADS equipped airdrop bundles encased in fairings on orbits over areas where troops were likely to be in contact or where small teams were operating independently. These bundles would then be available nearly instantaneously to support ground forces if needed in an emergency situation. The rest of the categories are largely self-explanatory with the exception of "Low-Cost, Low-Altitude airdrop". The concept for this category was to free manned aircraft from this low-weight airdrop mission so they can focus on more strategic airlift, personnel transport and aeromedical evacuation missions. This would be accomplished by procuring MQ-9s with a degraded sensor suite and no ISR Processing, Exploitation and Dissemination (PED) tail, which creates most of the personnel burden associated with RPA orbits.

For the third question, “What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?”, responses were as follows:

Table 7. Consolidated first round responses to question 3 for second round

Responses	**Rank Order 1-9**
Airdrop could compete unfavorably against other missions for the MQ-9	
Maximum weapons load reduced if airdrop payloads utilized	
Execution delays at drop time due to satellite link delays	
Requires specially designed external pods to contain payload	
Less flexibility than manned aircraft for dynamic changes	
Cannot resupply units without a suitable DZ	
Creates need for secure MQ-9 launch locations close to area of employment	
Airdrop pods will reduce time on station for ISR missions due to weight & drag	
Limited payload	

All but two of the responses for question three were self-explanatory and expected based on basic physics and geography considerations. The question of competition for MQ-9s will largely depend on how many are procured, how many pilots are trained and whether sensor advances such as “Gorgon Stare”, the multi-FMV system in development, succeeds in increasing feeds per aircraft to the planned 65. The topic of RPA having “Less flexibility than manned aircraft for dynamic changes” also remains to be proven. Given current capabilities, this appears to be true prima facie, but with improvements in sensor configuration and fidelity, as well as human factors considerations for pilots and sensor operators, this concern may not prove to be enduring.

For the fourth question, "What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?", responses were as follows:

Table 8. Consolidated first round responses to question 4 for second round

Responses	**Rank Order 1-10**
Development of JPADS capable pods & payloads to hang externally	
Flight profiles & defensive systems to improve survivability at low altitudes	
Joint training to mitigate seams between MQ-9 operators, customers & support	
Tactics, Techniques and Procedure (TTP) & concept of employment development	
Display software updates to provide an airdrop damage hazard area overlay	
Integration with other resupply platforms, ground stations & ground forces	
Upgrade to allow automated airdrop execution with satellite signal loss	
Joint development team to ensure compatibility of interfaces	
Modifications to carry & deploy dropsondes for wind collection	
Dedicated MQ-9s w/o ISR Processing, Exploitation & Dissemination (PED) tail	

Question four was perhaps the most open ended question as it dealt with ways to mitigate potential problems across the full spectrum of initiating an RPA airdrop mission set with the MQ-9. The topics were able to be compressed in the survey format without an excessive loss of fidelity. Question four did, however, require 10 topics, more than the other three questions. The only topic which may not be self-explanatory outside the panel is the "airdrop damage hazard area overlay". The concept submitted by multiple panel members was to utilize the TGP display software to provide a visual airdrop damage hazard area overlay. This would allow a DZCO to visualize expected airdrop dispersion and circular error. The DZCO could then shift the PI in real time to mitigate risk, providing a true dynamic airdrop capability even in locations which had not been surveyed previously for airdrop operations.

Final Round 4 Rankings

The final simple average rankings to each question are presented below. The rankings for "What are the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft?", were as follows:

Table 9. Consolidated final average rankings to question 1

Responses	**Average Ranking**
Imagery & PI coordinate updates in dynamic environment	2.33
Search & C2 in a Personnel Recovery (PR) with ability to re-supply the survivor(s)	3.11
Drop Zone Control Officer (DZCO), C2, & manned aircraft communications relay	4.0
DZ Wind Analysis	4.22
Airdrop of small items: i.e. ground sensors, robots, or Information Ops leaflets	4.67
Enable remote DZCO operation with no control personnel on the ground	4.89
Resupply of small units	6.11
Visual Guidance, Navigation & Control (GNC) for GPS denied airdrop	6.67

For the second question, "What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?", rankings were as follows:

Table 10. Consolidated final average rankings to question 2

Responses	Average Ranking
Mitigate risk to manned aircraft in elevated threat environments	2.78
Airdrop of unattended ground sensors in real-time support of ISR missions	3.33
Wind Analysis to eliminate current need for multiple passes by manned aircraft	3.67
Provide persistent availability of emergency resupply on routine ISR missions	4.33
Nuclear, biological, chemical, radiological (NBCR) environment airdrop operations	4.67
Airdrop of Unmanned Ground Systems (UGSs) in elevated threat areas	5.0
24/7/365 alert to launch for emergency airdrop missions	5.44
Low-Cost, Low-Altitude airdrop	6.78

For the third question, "What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?", rankings were as follows:

Table 11. Consolidated final average rankings to question 3

Responses	Average Ranking
Airdrop could compete unfavorably against other missions for the MQ-9	2.11
Limited payload	2.89
Maximum weapons load reduced if airdrop payloads utilized	3.67
Airdrop pods will reduce time on station for ISR missions due to weight & drag	4.11
Requires specially designed external pods to contain payload	5.11
Creates need for secure MQ-9 launch locations close to area of employment	5.22
Less flexibility than manned aircraft for dynamic changes	6.11
Execution delays at drop time due to satellite link delays	7.33
Cannot resupply units without a suitable DZ	8.22

For the fourth question, “What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?”, rankings were as follows:

Table 12. Consolidated final average rankings to question 4

Responses	**Average Ranking**
Dedicated MQ-9s w/o ISR Processing, Exploitation & Dissemination (PED) tail	3.56
Development of JPADS capable pods & payloads to hang externally	3.67
Integration with other resupply platforms, ground stations & ground forces	3.89
Joint training to mitigate seams between MQ-9 operators, customers & support	4.11
Modifications to carry & deploy dropsondes for wind collection	4.89
Joint development team to ensure compatibility of interfaces	5.44
Tactics, Techniques and Procedure (TTP) & concept of employment development	6.33
Upgrade to allow automated airdrop execution with satellite signal loss	6.56
Display software updates to provide an airdrop damage hazard area overlay	7.56
Flight profiles & defensive systems to improve survivability at low altitudes	9.0

Panel Inputs from Round 3

Panel members provided several inputs during the third round in order to explain their position and potentially sway other panel members in round four. Regarding the first question, the following inputs were provided. From the AFSOC MQ-9 expert: “My ranking changes…were slight. They are mainly due to the poor [line-of-sight] radio comm. currently available on the MQ-9.” From the USAF AMC respondent: “DZ wind analysis is the most useful (#1) because ballistic wind profiles are the main cause of our airdrop inaccuracies.” Also from the USAF AMC respondent was the input that “Search and C2 in a PR w/ ability to resupply is less useful (#8) than current order because this is not a mission gap--HC-130 personnel may be on-scene commander, airborne mission commander (if more capable C2 asset such as AWACS or JSTARS is unavailable), or rescue mission commander as well as both personnel and CDS (and CDS-variant) airdrops." Finally, from an MQ-1 Pilot: "CSAR becomes the #1 priority in nearly every AOR once it occurs, and there exist many papers and discussion of the CSAR capabilities of the RPA in terms of armed overwatch, connectivity, weapons employments and with your recommendation possible resupply. An argument against it may be however, the average time a[n] IP (isolated person) spends on the ground in recent actions (Libya)…is measured not in days but hours. Finally RPA do NOT do well in a completely GPS degraded environment."

For question two the following inputs were received. From the USAF AMC respondent: "Wind analysis is the most advantageous (#1) because ballistic wind profiles are the main cause of our airdrop inaccuracies." Also from the USAF AMC respondent: "Airdrop of unattended ground sensors is less advantageous (#5) because current airdrop platforms could perform this mission today from a variety of altitudes and/or delivery methods." The USAF AMC respondent also provided the following input: "NBCR environment airdrop is less significantly advantageous (#7) than potential to support both emergency airdrop and airdrop in elevated threat areas." The MQ-1 Pilot responded that "The RPA would do well in an NBC environment, unsure about the decon procedures however. It's interesting to think of the RPA as low cost, I would be curious to extract a precise flying hour cost of the RPA. Consider, the [g]round control station, manning (always the least expensive) fiber and satellite bandwidth, contractor support, [l]aunch and recover establishment and finally aircraft maintenance and availability. We are far from rapidly deployable, I would argue, and it still takes a few weeks to get spun up (no matter who is pushing for it)."

On the third question, the only input was from the MQ-1 Pilot: "Currently the MQ-9 mission set is limited, with a pod or flexible configuration adaptations become easier, as I know you aware of [G]orgon [S]tare, there exists zero kinetic capability and once it is a stare bird it remains…"

For the fourth question, the only input was from the AFSOC MQ-9 expert: ""My ranking changes to question 8 deal with prioritizing [j]oint development team prior to joint training and TTP development. There are so many different upgrades to the MQ-9 being accomplished for different users and a large part of the MQ-9 interface is with the [j]oint user on the ground. Starting out with a robust joint team will help ensure MQ-9 Mobility upgrades support the [j]oint community."

Panel Inputs from Round 4

For the fourth round, respondents were encouraged to provide inputs to any rankings they felt strongly about. Three respondents took this opportunity. On question one, the expert from the US Army's Logistics Innovation Agency (LIA) responded that "As a logistician, one of the primary issues in getting resupplies to Soldiers is how to counter the threat to ground convoys. Our analysis shows that aerial delivery offers one of the best options to accomplish this mission. Our study recognizes that a Cargo unmanned aerial system (Cargo UAS) or Remotely Piloted Vehicle will not be able to replace road convoys, but would greatly supplement the aerial delivery of supplies. Additionally, we discovered that anywhere from 25% – 30% of the Combat Outpost in Afghanistan are situated in places where aerial delivery is the only possibility for resupply them. With that viewpoint in mind, I rank ordered the following response accordingly."

The USAF AMC respondent took the opportunity to highlight the concern the MQ-1 Pilot raised concerning operations in GPS degraded environments.

For question two, the JPADS senior project manager responded that "The main benefit of MQ-9[s] is that they are already in the air and paid for. Piggybacking missions without dramatically [a]ffecting the primary ISR mission would seem to be the first things that can be done successfully. If an MQ-9 is flying around doing ISR, it would seem that the winds wherever it is flying can be ascertained just from the actual flight profile of the MQ-9 vs what it would fly without wind. If there was an automated way that this wind could be passed to a central repository, in a standard format, then we wouldn't be affecting its mission at all (maybe eating up some bandwidth intermittently at the most) and we'd gain valuable information to conduct weather forecasts." The LIA respondent contributed that "From our research and analysis, we discovered one of the best ways to supply small, dispersed units [is] with loads that can be delivered with precision. There are a couple of airdrop delivery methods, Low Cost, Low Altitude (LCLA), joint Precision Airdrop System (JPADS) and freedrop. [LCLA and freedrop] require a delivery profile that requires the aircraft to operate low and slow to the intended target. Both LCLA and freedrop allow resupplies to be placed precisely on the intended spot. However because of the profile, it also requires the flight crew to be placed in harm's way from shoulder fired weapons. A RPA performing these same resupply missions would not put flight crew in harm's way."

For question three, the LIA respondent raised the concerns that "First, the MQ-9 would have to have specially designed and tested pods to carry cargo. If it did not have the pods, the MQ-9 would have to sling load its payload. Just because of physics of sling loading cargo, airspeed of the MQ-9 would be tremendously decreased…Second with a cargo payload capability of only 2000 lbs, the MQ-9 would either have to make many sorties to resupply a unit or the MQ-9 would be limited to time-sensitive/emergency resupply missions."

On question four, the USAF AMC respondent highlighted the AFSOC MQ-9 expert's concern that "Starting out with a robust joint team will help ensure MQ-9 Mobility upgrades support the Joint community."

Limitations

There are several limitations to the generalizability of this study. Firstly, there was no General Officer, Flag Officer or Senior Executive Service (SES) participation in the research, despite numerous requests. The highest levels of participation were GS-15 and O-5. This provided for a robust expert panel, but did not include the senior decision maker perspective desired. This was unusual for studies by students in Air Mobility Command's Advanced Study of Air Mobility Program as previous and current researchers had multiple responses provided by General Officers. The researcher in this study was met with varying levels of resistance by front office staffs for attempting to survey leaders above the O-6 or GS-15 level.

A second limitation was the lack of participation from the Air Force Logistician Community or any communications or analysis experts. The researcher understands the logistician and communications communities are under extreme stress due to overseas deployments and this is the likely cause. It is also likely that the support required for RPA airdrop would not differ significantly from support currently provided, but without input from maintainers, logisticians and communications specialists it is not possible to make that determination. The lack of analyst participation was disappointing as that community has a great number of civilians with long-term perspectives; supports lessons learned; and often has a holistic view of problems not attainable by the functional staff experts.

The final limitation was the low participation rate overall and specifically with respect to AMC and USTRANSCOM. Only 1 of 19 offices and individuals contacted at AMC and USTRANSCOM participated in any rounds of this study. Fortunately, the individual was an airdrop expert and participated fully throughout all four rounds. It is unlikely, however, that this AMC sponsored program can produce quality results in the future if increased emphasis on participation by the transportation community is not encouraged by the parent command. In this case, high participation by the US Army and USSOCOM largely supplanted the lack of AMC and USTRANSCOM participation, although the lack of any participation by the communications community is a weakness. Additionally, the lack of General Officers, Flag Officers and SES members on the panel does diminish the impact of the research and limits it to an experts-only study.

Future Research

The first area for future research would be to obtain General Officer, Flag Officer and SES participation in a Delphi Study to determine the intersection of expert and senior leader opinions regarding RPA airdrop. This research could be illuminating for a future senior leader making decisions concerning RPA airdrop by indicating areas of agreement and contention between the strategic and operational thought processes.

The second area for research would be in RPA airdrop past the MQ-9. It is imperative that RPA airdrop requirements be injected quickly into the development of MQ-Ma, MQ-La, and beyond to avoid being faced with a situation in the future where the capability is required but not available. This research could also be conducted through a Delphi Study to determine requirements for RPA airdrop without the MQ-9 restriction placed on this research. The study could be bounded with weight limits that MQ-M and MQ-L are capable of obtaining, but with an early inject into the planning phase, further restrictions would not be necessary or desirable.

A third area for further research is actual engineering development of demonstration airdrop pods, control software modifications, integration, and actual technology demonstration. This research would be perfect for a joint venture between AFIT, the Air Force Research Laboratory and the US Army Natick Soldier Research, Development and Engineering Center.

Conclusions and Recommendations

Powerful militaries and celebrated generals have been humbled throughout history by a lack of effective logistics planning. Alexander the Great, Napoleon, Lee, German Army Group B, and even Patton and Bradley have suffered grave losses of battles, campaigns and even wars through a failure to fully appreciate their logistics needs (Bartlow, 1988). This research attempts to support advancement in one small but critical aspect of modern expeditionary logistics; airdrop.

Manned airdrop can provide significant flexibility for resupplying troops to a UCC, but comes with three main risks. The first is the risk of loss of an asset costing as much as $202M and having multiple crew members aboard. The second is in the loss of efficient utilization of the asset, especially if attempting to provide persistent availability of resupply to small special operations teams. The final risk is in not utilizing the asset due to concern over the above risks, resulting in devastating consequences, such as in the "Lone Survivor" scenario. RPA airdrop reduces all of these risks, although not without some costs, either monetary or to other distinctive capabilities, such as information superiority.

This research, supported by the fantastic inputs of a truly joint and diverse expert panel, illuminated a great number of possible uses of the MQ-9 for airdrop. With regards to the airdrop missions the MQ-9 could be easily adapted to perform, the panel ranked imagery and PI coordinate updates in a dynamic environment as the most useful. The panel also highly ranked, in the following order, the utility of the MQ-9 in personnel recovery scenarios, to include resupplying the survivor; acting as a communications relay for a DZCO, C2, and manned airdrop aircraft; DZ wind analysis; the airdrop of small items such as unmanned sensors, robots or leaflets; and performing remote DZCO operation.

The panel believed there would be distinct advantages to be gained by MQ-9 airdrop over current manned airdrop platforms. The highest ranked response was mitigating risk to manned aircraft in elevated threat environments; followed by airdrop of unattended ground sensors in real-time support of ISR missions; wind analysis to eliminate the current need for multiple passes by manned aircraft; persistent availability of emergency resupply on routine ISR missions; nuclear, biological, chemical or radiological environment airdrop operations; and the airdrop of unmanned ground systems in elevated threat areas.

The panel was also asked to determine unavoidable drawbacks of utilizing the MQ-9 for airdrop. The panel rank ordered responses beginning with the concern that airdrop could compete unfavorably against other missions for the MQ-9; followed by the MQ-9 having a relatively limited payload capacity; the maximum weapons load being reduced if airdrop payloads are utilized; airdrop pods reducing time on station for ISR missions due to weight and drag; requiring specially designed external pods to contain payload; and creating the need for secure MQ-9 launch locations close to the area of employment.

The panel was further asked to determine the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop. The rank ordered responses were procuring dedicated MQ-9s without an ISR PED tail; the development of JPADS capable pods and payloads to hang externally; integration with other resupply platforms, ground stations, and ground forces; joint training to mitigate seams between MQ-9 operators, customers, and support activities; modifications to carry and deploy dropsondes for wind collection; and utilizing a joint development team to ensure compatibility of interfaces.

The researcher's impression of the panel's overall opinion is that MQ-9 RPA capabilities should be developed to both support manned airdrop for large resupply missions and to conduct small, especially persistent, resupply missions autonomously. In a first round ranking of the admittedly broad statement "RPA could perform some air mobility missions," the panel returned a 4.78 on a scale of 5.0 with no score below a 4.0, with 5 being strongly agree. Due to the low number of participants, this is hardly statistically significant, but is indicative of these diverse and joint experts' strong view that RPA mission sets can expand into the realm of air mobility.

RPA airdrop development will greatly increase UCCs' freedom of action in elevated or denied threat areas as well as NBCR environments by removing the risk of loss of manned aircraft or harm to crews. The scheduled or emergency resupply of small special operations teams operating under hostile airspace, deployment of unmanned ground systems in denied territory and deployment of unattended sensors to NBCR sites are just a few of the new missions that RPA airdrop will enable. With regards to existing airdrop mission sets, both risk and cost can be greatly reduced through the effective employment of MQ-9s in sub-2,000 pound airdrop scenarios. These missions could be performed extremely efficiently through utilizing unused payload capacity on targeted existing orbits, or more effectively, and still far more efficiently than with manned aircraft, by acquiring dedicated AMC MQ-9s (perhaps CQ-9s) without the costly ISR PED tail.

This study should be utilized as a baseline for future RPA airdrop development as well as a sanity check to ensure critical issues are not being overlooked. It could also serve as the initial research for a senior leader to determine whether to pursue RPA airdrop in the near-term with existing technologies. The research provides the collective views of a diverse selection of joint experts, representing all of the major stakeholders, regarding mission sets; advantages; disadvantages; and concerns that need to be addressed early to avoid failure or cost overruns in repurposing the MQ-9 Reaper for airdrop missions. Many of the results appear to be generalizable to future platforms such as MQ-Ma-c and MQ-La-c as well.

Finally, it should be noted that there was a significant lack of agreement amongst the panel, which is to be expected with an innovative concept affecting multiple stakeholders from various functional areas and joint communities. As this study was a Policy Delphi, this result is entirely appropriate and likely more useful to a senior leader than a report indicating high consensus. Rather, this study indicates the difficulties that will be encountered and the complex interactions that need to be considered in designing an airdrop capable RPA. With proper inputs, a solution can be reached which will avoid negatively impacting current ISR and hunter-killer missions while still providing the needed level of functionality to special operations and conventional users. The ultimate measure of the utility of RPA airdrop will be the increased effectiveness and efficiency of current airdrop mission sets and the development of new mission sets. It will fall to senior mobility leaders to engage the UCCs to determine the mix of requirements that will provide the greatest benefit to the nation while containing costs.

Appendix A. RPA Airdrop Questionnaire Round 1

Remotely Piloted Aircraft (RPA) Performing the Airdrop Mission Survey

Thank you for participating in this survey. I appreciate your time and candid responses. The sponsor for this research is Mr. Donald R. Anderson, AMC/AA9. The purpose of this research is to explore the practicality, benefits, drawbacks and difficulties of utilizing RPA for airdrop. In order to focus the research on the near term and considering current budget constraints, the questions are limited in scope to utilizing the MQ-9 Reaper. Please note the following:

1. Survey responses are confidential. Your identity (name or duty title) will not be associated with any responses you give in the final research report. Summarized responses will be releasable to the public under the Freedom of Information Act, but your identity and/or organizational information will not be associated with a questionnaire and will be known only by me. The survey is administered under Air Force Survey Control Number DAFAMCA910-115.

Privacy Act of 1974 and AFI 33-332

The Material / Information contained herein falls within the purview of the Privacy Act of 1974 and will be safeguarded in accordance with the applicable system of records notice and AFI 33-332. This survey is anonymous. No attempt to identify you or your organization will be made unless information indicates a credible or potential threat. By participating in this survey, you acknowledge that the information you provide, including the open text comments, may be viewed and released in accordance with the Freedom of Information Act. Do not include personal identifying information.

Operational Security (OPSEC), AFI 10-701

Do not provide OPSEC information. OPSEC is a process of identifying, analyzing and controlling critical information indicating friendly actions associated with military operations and other activities such as: 1) Identify those actions that can be observed by adversary intelligence systems. 2) Determine what specific indications could be collected, analyzed, and interpreted to derive critical information in time to be useful to adversaries. and 3) Select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitation. Comply with all OPSEC measures outlined in AFI 10-701. Do not provide critical information or indicators.

2. Please complete this survey **electronically** and return it to: patrick.farrell.2@us.af.mil.
   If you have questions on the survey or the survey process, I can also be reached at DSN 650-7741. Written correspondence can be addressed to:

   Maj Patrick Farrell
   USAF EC/MOS/ASAM 11
   5656 Texas Avenue; Room 403
   JB MDL, NJ 08640

3. Please complete this survey and return it electronically no later than **4 Feb 2011**.

4. There are 9 questions. The survey is "non-attribution", so please elaborate fully on your answers. Please do not collaborate with other individuals in the survey pool. Once all survey responses are received, you will be given the opportunity to revise your initial responses to questions 5-9 based on responses provided by the entire group. Subsequent rounds will be announced as needed and all research will conclude by May 2011.

Background:

1. Personal Information:
   a. Name:
   b. Rank/Grade:
   c. Current Duty Title:
   d. Time in Current Duty Position:
   e. Core AFSC/MOS/Primary Duty Code:

2. How many total years have you served on a staff above base/wing/division-level?

3. How many total years have you worked (been involved with) airdrop or RPA issues? Please specify airdrop or RPA and if both, please provide separate times for each.

4. Considering all of your staff roles, in what capacities have you dealt with airdrop or RPA issues? Please specify whether you answer is in respect to airdrop, RPA or both.

5. On a scale from 1 to 5 (1-strongly disagree, 3-neither agree/disagree, 5-strongly agree), please assess the statement, "RPA could perform some air mobility missions." Please elaborate on your response.

Please answer and elaborate on the following questions:

6. What are the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft? Do not provide names of individuals, units, or locations. Remember OPSEC guidance and do not provide classified information or other information which could compromise security.

7. What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop? Do not provide names of individuals, units, or locations. Remember OPSEC guidance and do not provide classified information or other information which could compromise security.

8. What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop? Do

not provide names of individuals, units, or locations. Remember OPSEC guidance and do not provide classified information or other information which could compromise security.

9. What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop? Do not provide names of individuals, units, or locations. Remember OPSEC guidance and do not provide classified information or other information which could compromise security.

Appendix B. RPA Airdrop Questionnaire Round 2

Remotely Piloted Aircraft (RPA) Performing the Airdrop Mission Survey

Thank you for participating in this survey. I appreciate your time and candid responses. The sponsor for this research is Mr. Donald R. Anderson, AMC/AA9. The purpose of this research is to explore the practicality, benefits, drawbacks and difficulties of utilizing RPA for airdrop. In order to focus the research on the near term and considering current budget constraints, the questions are limited in scope to utilizing the MQ-9 Reaper. Please note the following:

1. Survey responses are confidential. Your identity (name or duty title) will not be associated with any responses you give in the final research report. Summarized responses will be releasable to the public under the Freedom of Information Act, but your identity and/or organizational information will not be associated with a questionnaire and will be known only by me. The survey is administered under Air Force Survey Control Number DAFAMCA910-115.

Privacy Act of 1974 and AFI 33-332

The Material / Information contained herein falls within the purview of the Privacy Act of 1974 and will be safeguarded in accordance with the applicable system of records notice and AFI 33-332. This survey is anonymous. No attempt to identify you or your organization will be made unless information indicates a credible or potential threat. By participating in this survey, you acknowledge that the information you provide, including the open text comments, may be viewed and released in accordance with the Freedom of Information Act. Do not include personal identifying information.

Operational Security (OPSEC), AFI 10-701

Do not provide OPSEC information. OPSEC is a process of identifying, analyzing and controlling critical information indicating friendly actions associated with military operations and other activities such as: 1) Identify those actions that can be observed by adversary intelligence systems. 2) Determine what specific indications could be collected, analyzed, and interpreted to derive critical information in time to be useful to adversaries. and 3) Select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitation. Comply with all OPSEC measures outlined in AFI 10-701. Do not provide critical information or indicators.

2. Please complete this survey electronically and return it to patrick.farrell.2@us.af.mil. If you have questions on the survey or the survey process, I can also be reached at DSN 650-7741. Written correspondence can be addressed to:

Maj Patrick Farrell
USAF EC/MOS/ASAM 11
5656 Texas Avenue; Room 403
JB MDL, NJ 08640

3. Please complete this survey and return it electronically no later than **15 Mar 2011**.

4. There are 4 topics to rank order. Subsequent rounds will be announced as needed to reach consensus and all research will conclude by May 2011.

These questions will determine the importance amongst the criteria chosen by the panel. Please rank-order the criteria below with the number 1 being the best answer (or of most importance with respect to the question). If you feel that a response is not-applicable or is impossible based on your expert knowledge, please still rank order that response, but include a comment as to why the item should be removed.

5. Of the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft, which is most useful?

Responses	**Rank Order 1-8**
Imagery & PI coordinate updates in dynamic environment	
DZ Wind Analysis	
Resupply of small units	
Airdrop of small items: i.e. ground sensors, robots, or Information Ops leaflets	
Drop Zone Control Officer (DZCO), C2, & manned aircraft communications relay	
Search & C2 in a Personnel Recovery (PR) with ability to re-supply the survivor(s)	
Enable remote DZCO operation with no control personnel on the ground	
Visual Guidance, Navigation & Control (GNC) for GPS denied airdrop	

6. What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?

Responses	**Rank Order 1-8**
Mitigate risk to manned aircraft in elevated threat environments	
Provide persistent availability of emergency resupply on routine ISR missions	
Wind Analysis to eliminate current need for multiple passes by manned aircraft	
Airdrop of unattended ground sensors in real-time support of ISR missions	
Airdrop of Unmanned Ground Systems (UGSs) in elevated threat areas	
Nuclear, biological, chemical, radiological (NBCR) environment airdrop operations	

24/7/365 alert to launch for emergency airdrop missions	
Low-Cost, Low-Altitude airdrop	

7. What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?

Responses	**Rank Order 1-9**
Airdrop could compete unfavorably against other missions for the MQ-9	
Maximum weapons load reduced if airdrop payloads utilized	
Execution delays at drop time due to satellite link delays	
Requires specially designed external pods to contain payload	
Less flexibility than manned aircraft for dynamic changes	
Cannot resupply units without a suitable DZ	
Creates need for secure MQ-9 launch locations close to area of employment	
Airdrop pods will reduce time on station for ISR missions due to weight & drag	
Limited payload	

8. What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?

Responses	**Rank Order 1-10**
Development of JPADS capable pods & payloads to hang externally	
Flight profiles & defensive systems to improve survivability at low altitudes	
Joint training to mitigate seams between MQ-9 operators, customers & support	
Tactics, Techniques and Procedure (TTP) & concept of employment development	
Display software updates to provide an airdrop damage hazard area overlay	
Integration with other resupply platforms, ground stations & ground forces	
Upgrade to allow automated airdrop execution with satellite signal loss	
Joint development team to ensure compatibility of interfaces	
Modifications to carry & deploy dropsondes for wind collection	
Dedicated MQ-9s w/o ISR Processing, Exploitation & Dissemination (PED) tail	

Appendix C. RPA Airdrop Questionnaire Round 3

Remotely Piloted Aircraft (RPA) Performing the Airdrop Mission Survey

Thank you for participating in this survey. I appreciate your time and candid responses. The sponsor for this research is Mr. Donald R. Anderson, AMC/AA9. The purpose of this research is to explore the practicality, benefits, drawbacks and difficulties of utilizing RPA for airdrop. In order to focus the research on the near term and considering current budget constraints, the questions are limited in scope to utilizing the MQ-9 Reaper. Please note the following:

1. Survey responses are confidential. Your identity (name or duty title) will not be associated with any responses you give in the final research report. Summarized responses will be releasable to the public under the Freedom of Information Act, but your identity and/or organizational information will not be associated with a questionnaire and will be known only by me. The survey is administered under Air Force Survey Control Number DAFAMCA910-115.

Privacy Act of 1974 and AFI 33-332

The Material / Information contained herein falls within the purview of the Privacy Act of 1974 and will be safeguarded in accordance with the applicable system of records notice and AFI 33-332. This survey is anonymous. No attempt to identify you or your organization will be made unless information indicates a credible or potential threat. By participating in this survey, you acknowledge that the information you provide, including the open text comments, may be viewed and released in accordance with the Freedom of Information Act. Do not include personal identifying information.

Operational Security (OPSEC), AFI 10-701

Do not provide OPSEC information. OPSEC is a process of identifying, analyzing and controlling critical information indicating friendly actions associated with military operations and other activities such as: 1) Identify those actions that can be observed by adversary intelligence systems. 2) Determine what specific indications could be collected, analyzed, and interpreted to derive critical information in time to be useful to adversaries. and 3) Select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitation. Comply with all OPSEC measures outlined in AFI 10-701. Do not provide critical information or indicators.

2. Please complete this survey electronically and return it to patrick.farrell.2@us.af.mil. If you have questions on the survey or the survey process, I can also be reached at DSN 650-7741. Written correspondence can be addressed to:

Maj Patrick Farrell
USAF EC/MOS/ASAM 11
5656 Texas Avenue; Room 403
JB MDL, NJ 08640

3. Please complete this survey and return it electronically no later than **5 Apr 2011**.

4. There are 4 topics to rank order. Subsequent rounds will be announced as needed to reach consensus and all research will conclude by May 2011.

These questions will determine the importance amongst the criteria chosen by the panel. Please rank-order the criteria below with the number 1 being the best answer (or of most importance with respect to the question). If you feel that a response is not-applicable or is impossible based on your expert knowledge, please still rank order that response, but include a comment as to why the item should be removed.

5. Of the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft, which is most useful?

Responses	**Rank Order 1-8**
Imagery & PI coordinate updates in dynamic environment	
Search & C2 in a Personnel Recovery (PR) with ability to re-supply the survivor(s)	
DZ Wind Analysis	
Drop Zone Control Officer (DZCO), C2, & manned aircraft communications relay	
Airdrop of small items: i.e. ground sensors, robots, or Information Ops leaflets	
Enable remote DZCO operation with no control personnel on the ground	
Visual Guidance, Navigation & Control (GNC) for GPS denied airdrop	
Resupply of small units	

6. What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?

Responses	**Rank Order 1-8**
Mitigate risk to manned aircraft in elevated threat environments	
Airdrop of unattended ground sensors in real-time support of ISR missions	
Wind Analysis to eliminate current need for multiple passes by manned aircraft	
Provide persistent availability of emergency resupply on routine ISR missions	
Nuclear, biological, chemical, radiological (NBCR) environment airdrop operations	
24/7/365 alert to launch for emergency airdrop missions	
Airdrop of Unmanned Ground Systems (UGSs) in elevated threat areas	
Low-Cost, Low-Altitude airdrop	

7. What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?

Responses	**Rank Order 1-9**
Airdrop could compete unfavorably against other missions for the MQ-9	
Limited payload	
Airdrop pods will reduce time on station for ISR missions due to weight & drag	
Maximum weapons load reduced if airdrop payloads utilized	
Requires specially designed external pods to contain payload	
Creates need for secure MQ-9 launch locations close to area of employment	
Less flexibility than manned aircraft for dynamic changes	
Execution delays at drop time due to satellite link delays	
Cannot resupply units without a suitable DZ	

8. What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?

Responses	**Rank Order 1-10**
Development of JPADS capable pods & payloads to hang externally	
Dedicated MQ-9s w/o ISR Processing, Exploitation & Dissemination (PED) tail	
Integration with other resupply platforms, ground stations & ground forces	
Modifications to carry & deploy dropsondes for wind collection	
Joint training to mitigate seams between MQ-9 operators, customers & support	
Upgrade to allow automated airdrop execution with satellite signal loss	
Tactics, Techniques and Procedure (TTP) & concept of employment development	
Joint development team to ensure compatibility of interfaces	
Flight profiles & defensive systems to improve survivability at low altitudes	
Display software updates to provide an airdrop damage hazard area overlay	

Appendix D. RPA Airdrop Questionnaire Round 4

Remotely Piloted Aircraft (RPA) Performing the Airdrop Mission Survey

Thank you for participating in this survey. I appreciate your time and candid responses. The sponsor for this research is Mr. Donald R. Anderson, AMC/AA9. The purpose of this research is to explore the practicality, benefits, drawbacks and difficulties of utilizing RPA for airdrop. In order to focus the research on the near term and considering current budget constraints, the questions are limited in scope to utilizing the MQ-9 Reaper. Please note the following:

1. Survey responses are confidential. Your identity (name or duty title) will not be associated with any responses you give in the final research report. Summarized responses will be releasable to the public under the Freedom of Information Act, but your identity and/or organizational information will not be associated with a questionnaire and will be known only by me. The survey is administered under Air Force Survey Control Number DAFAMCA910-115.

Privacy Act of 1974 and AFI 33-332

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Operational Security (OPSEC), AFI 10-701

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2. Please complete this survey electronically and return it to patrick.farrell.2@us.af.mil. If you have questions on the survey or the survey process, I can also be reached at DSN 650-7741. Written correspondence can be addressed to:

Maj Patrick Farrell
USAF EC/MOS/ASAM 11
5656 Texas Avenue; Room 403
JB MDL, NJ 08640

3. Please complete this survey and return it electronically no later than **2 May 2011**.

4. There are 4 topics to rank order. This is the final round.

These questions will determine the importance amongst the criteria chosen by the panel. Please rank-order the criteria below with the number 1 being the best answer (or of most importance with respect to the question). If you feel that a response is not-applicable or is impossible based on your expert knowledge, please still rank order that response, but include a comment as to why the item should be removed.

5. Of the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft, which is most useful?

Remarks from panel members:

AFSOC - "My ranking changes to question 5 were slight. They are mainly due to the poor radio comm. currently available on the MQ-9 (1 radio that has bad reception and transmission problems with ground forces below aircraft)."

USAF AMC – "DZ wind analysis is the most useful (#1) because ballistic wind profiles are the main cause of our airdrop inaccuracies."

USAF AMC – "Search and C2 in a PR w/ ability to resupply is less useful (#8) than current order because this is not a mission gap--HC-130 personnel may be on-scene commander, airborne mission commander (if more capable C2 asset such as AWACS or JSTARS is unavailable), or rescue mission commander as well as both personnel and CDS (and CDS-variant) airdrops."

MQ-1 Pilot – "CSAR becomes the #1 priority in nearly every AOR once it occurs, and there exist many papers and discussion of the CSAR capabilities of the RPA in terms of armed overwatch, connectivity, weapons employments and with your recommendation possible resupply. An argument against it may be however, the average time a IP (isolated person) spends on the ground in recent actions (Libya) it is measured not in days but hours. Finally RPA do NOT do well in a completely GPS degraded environment."

Responses	**Rank Order 1-8**
Imagery & PI coordinate updates in dynamic environment	
Search & C2 in a Personnel Recovery (PR) with ability to re-supply the survivor(s)	
Drop Zone Control Officer (DZCO), C2, & manned aircraft communications relay	
DZ Wind Analysis	
Airdrop of small items: i.e. ground sensors, robots, or Information Ops leaflets	

Enable remote DZCO operation with no control personnel on the ground	
Visual Guidance, Navigation & Control (GNC) for GPS denied airdrop	
Resupply of small units	

6. What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?

Remarks from panel members:

USAF AMC – "Wind analysis is the most advantageous (#1) because ballistic wind profiles are the main cause of our airdrop inaccuracies."

USAF AMC – "Airdrop of unattended ground sensors is less advantageous (#5) because current airdrop platforms could perform this mission today from a variety of altitudes and/or delivery methods."

USAF AMC – "NBCR environment airdrop is less significantly advantageous (#7) than potential to support both emergency airdrop and airdrop in elevated threat areas."

MQ-1 Pilot – "The RPA would do well in an NBC environment, unsure about the decon procedures however. It's interesting to think of the RPA as low cost, I would be curious to extract a precise flying hour cost of the RPA. Consider, the Ground control station, manning (always the least expensive) fiber and satellite bandwidth, contractor support, Launch and recover establishment and finally aircraft maintenance and availability. We are far from rapidly deployable, I would argue, and it still takes a few weeks to get spun up (no matter who is pushing for it)."

Responses	**Rank Order 1-8**
Mitigate risk to manned aircraft in elevated threat environments	
Airdrop of unattended ground sensors in real-time support of ISR missions	
Wind Analysis to eliminate current need for multiple passes by manned aircraft	
Provide persistent availability of emergency resupply on routine ISR missions	
Nuclear, biological, chemical, radiological (NBCR) environment airdrop operations	
Airdrop of Unmanned Ground Systems (UGSs) in elevated threat areas	
24/7/365 alert to launch for emergency airdrop missions	
Low-Cost, Low-Altitude airdrop	

7. What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?

Remarks from panel members:

MQ-1 Pilot – "Currently the MQ-9 mission set is limited, with a pod or flexible configuration adaptations become easier, as I know you aware of gorgon stare, there exists zero kinetic capability and once it is a stare bird it remains (from what I've read)."

Responses	**Rank Order 1-9**
Airdrop could compete unfavorably against other missions for the MQ-9	
Limited payload	
Maximum weapons load reduced if airdrop payloads utilized	
Airdrop pods will reduce time on station for ISR missions due to weight & drag	
Requires specially designed external pods to contain payload	
Creates need for secure MQ-9 launch locations close to area of employment	
Less flexibility than manned aircraft for dynamic changes	
Execution delays at drop time due to satellite link delays	
Cannot resupply units without a suitable DZ	

8. What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?

Remarks from panel members:

AFSOC - “My ranking changes to question 8 deal with prioritizing Joint development team prior to joint training and TTP development. There are so many different upgrades to the MQ-9 being accomplished for different users and a large part of the MQ-9 interface is with the Joint user on the ground. Starting out with a robust joint team will help ensure MQ-9 Mobility upgrades support the Joint community.”

Responses	**Rank Order 1-10**
Dedicated MQ-9s w/o ISR Processing, Exploitation & Dissemination (PED) tail	
Development of JPADS capable pods & payloads to hang externally	
Integration with other resupply platforms, ground stations & ground forces	
Joint training to mitigate seams between MQ-9 operators, customers & support	
Modifications to carry & deploy dropsondes for wind collection	
Joint development team to ensure compatibility of interfaces	
Tactics, Techniques and Procedure (TTP) & concept of employment development	
Upgrade to allow automated airdrop execution with satellite signal loss	
Display software updates to provide an airdrop damage hazard area overlay	
Flight profiles & defensive systems to improve survivability at low altitudes	

Appendix E. Human Subject Exemption Approval AFIT

November 22, 2010

Lt Col Joseph Skipper,

I have reviewed your study concerning Remotely Piloted Aircraft (RPA) Performing the Airdrop Mission and found that your study qualifies for an IRB exemption.

Per 32 CFR 219.101 (b)(2), Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation is exempt.

Your study qualifies for this exemption because the demographic data you are collecting cannot realistically be expected to map a given response to a specific subject, and the questions you are asking could not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. Finally, while you are collecting names, this is a required and natural consequence of your selected data collection methodology. These names will be protected at all times, only be known to the researchers, and managed according to the AFIT interview protocol.

This determination pertains only to the Federal, DoD, and Air Force regulations that govern the use of human subjects in research. It does not constitute final approval to conduct the study which should be granted by you research advisor. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

WILLIAM A. CUNNINGHAM, PhD
AFIT IRB Research Reviewer

Appendix F. Human Subject Exemption Approval AF Survey Office

AIR FORCE SURVEY OFFICE
RESEARCH REVIEW DETERMINATION

Project Title: Remotely Piloted Aircraft Performing the Airdrop Mission Survey

Project Number: DAFAMCA910-115

Principal Investigator: Maj Patrick Farrell on behalf of Mr. Donald R. Anderson

____ This activity does not involve human subjects or it is not research.

_X _ This human subject research is eligible for exemption under Category __2___.

Changes to the operational test or safety plan/research plan/proposal may affect the exempt status and must be reviewed by the Air Force Survey Office.

_____ This human subject research is referred to _________________________ for further review or consideration.

Research Reviewer: Dr. Donna-Mischell Navarro

Date: 01/02/2011

Signature: //Signed, D.M. Navarro//

Research review conducted IAW Human Research Protection Program guidance; 32 CFR 219 and AFI 40-402.

Appendix G. AF Survey Office Survey Control Number

4 Jan 2011

MEMORANDUM FOR MR. DONALD R. ANDERSON

FROM: AFMA/MAPP
550 E Street East, Suite 116
Randolph AFB TX 78150-4451

SUBJECT: Request for Survey Approval

1. The Remotely Piloted Aircraft Performing the Airdrop Mission Survey is approved for use with Air Force active duty and civilian participants. A Survey Control Number (SCN) of USAF SCN DAFAMCA910-115 is assigned and valid through 1 Jun 2011. Please ensure SCN and expiration date are stated in the introductory protocol and on all survey administration documents.

2. Please ensure compliance to the following guidance, as applicable:

a. IAW AFI 33-129, all websites hosted in the commercial environment (i.e. .com, .org, etc,), require SAF/XC approval. Send the SCN form with the survey to safscio.networkdivi@pentagon.af.mil to request a waiver from requirements.

b. IAW AFI 64-106, surveys administered to bargaining unit civilian employees require Labor Relations coordination. Contact AFPC/DPIEC at DSN 665-5737 for approval.

c. The public may request survey results IAW the Freedom of Information Act (FOIA). Results released outside Air Force require pre-coordination with Air Force Public Affairs.

d. IAW AFI 33-119 and AFSSI 8520, official correspondence requires a digital certificate. For PK enabling (PKE) information go to https://afpki.lackland.af.mil/html/pkenabling.cfm. For .mil systems refer to AF PKI at https://afpki.lackland.af.mil/html/help_desk.cfm. For non-mil systems refer to http://iase.disa.mil/pki/eca/. For information on External Certificate Authority or to contact a representative go to http://iase.disa.mil/pki/eca/contact_us.html.

3. We wish you great success with your data collection effort.

//Signed//
DR. DONNA-MISCHELL NAVARRO
Personnel Psychologist, Air Force Survey Office

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Vita

Education

MAS	2009	Embry-Riddle Aeronautical University, Aeronautical Science
BA	1999	University of Massachusetts, Amherst, Journalism

Employment History

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2009 - 2010	C-17 FTU Evaluator Aircraft Commander, Chief Executive Officer; 97 AMW, Altus AFB OK
2007 - 2009	C-17 FTU Evaluator Aircraft Commander, Resource Advisor; 97 OG, Altus AFB OK
2005 - 2007	C-17 Special Operations Evaluator Aircraft Cmdr, Flight Cmdr; 17 AS, Charleston AFB SC
2004 - 2005	C-17 Aircraft Commander, Chief of Safety; 17 AS, Charleston AFB SC
2001 - 2004	C-17 Pilot, Executive Officer; 17 AS, Charleston AFB SC
2000 - 2001	Student, Undergraduate Pilot Training; Vance AFB OK
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Word Count: 748

Saving Lives and Opening New Battlespace with RPA Airdrop

This study was inspired by conversations with the former commander of Air Mobility Command in 2007 regarding an unfilled need for persistent, on-call, precision airdrop. The need has been highlighted repeatedly in Afghanistan, most memorably when a four man Navy SEAL patrol was attacked in 2005 by 100 enemy combatants. If heavy weapons and medical equipment had been available overhead, able to be called in on short notice, perhaps more than one SEAL would have survived. The reason the Air Force was unable to provide persistent airdrop support was simply a matter of available platforms, not technology.

Manned airdrop can provide flexibility for resupplying troops to a UCC, but comes with three main risks. The first is the loss of an asset with multiple crew members costing as much as $202M. The second is the loss of efficient utilization of the asset, especially if attempting to provide persistency. The final risk is not utilizing the asset for the resupply mission due to the above risks. RPA airdrop reduces all of these risks, although not without some costs, both monetary and to other distinctive capabilities.

In order to make the research feasible in a constrained budgetary environment, this study is bounded within the General Atomics MQ-9 Reaper RPA, which is uniquely qualified from a cost, capability and availability standpoint to support new and current roles simultaneously. This research, supported by a joint and diverse expert panel, illuminates many possible uses of the MQ-9 for airdrop. There was representation from AMC, ACC, AFSOC, the MQ-9 SPO, the

Army Logistics Innovation Agency and the Airdrop/Aerial Delivery Directorate of the Natick Soldier RD&E Center; encompassing intelligence, operations, logistics, procurement, and plans.

With regards to the airdrop missions the MQ-9 could be easily adapted to perform, imagery and PI coordinate updates in a dynamic environment ranked highest; followed by the utility of the MQ-9 in PR, including resupplying the survivor; communications relay for manned airdrop; DZ wind analysis; and the airdrop of sensors, robots or leaflets.

The panel believed there would be distinct advantages to MQ-9 airdrop over manned platforms. The highest ranked was mitigating risk to manned aircraft in elevated threat environments; followed by airdrop of unattended ground sensors in real-time support of ISR; wind analysis, to eliminate the current need for multiple passes by manned aircraft; persistent availability of emergency resupply on routine ISR missions; and NBCR environment airdrop.

The panel was also asked to determine unavoidable drawbacks and difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop. These are identified in the full paper and should be considered before implementation, but none represent insurmountable barriers.

RPA airdrop will greatly increase UCCs' freedom of action in elevated or denied threat areas as well as NBCR environments by removing the risk of loss of manned aircraft. The scheduled or emergency resupply of small special operations teams operating under hostile airspace, deployment of unmanned ground systems in denied territory and deployment of sensors to NBCR sites are just a few of the new missions that RPA airdrop will enable. With regards to existing airdrop missions, both risk and cost can be greatly reduced through the effective employment of MQ-9s. These missions could be performed extremely efficiently through utilizing unused payload capacity in existing orbits, or more effectively, and still far more efficiently than with manned aircraft, by acquiring dedicated AMC MQ-9s without the costly ISR PED tail.

This study should be utilized as a baseline for future RPA airdrop development as well as a sanity-check. The research provides the collective views of a multi-functional panel of joint experts, representing all major stakeholders; regarding mission sets; advantages; disadvantages; and concerns that need to be addressed early to avoid failure or cost overruns in repurposing the MQ-9 Reaper for airdrop. Many of the results appear to be generalizable to future platforms such as MQ-M/L as well. With proper consideration, a solution can be reached which will avoid negatively impacting current ISR and hunter-killer missions while still providing the needed level of functionality to special operations and conventional users. The ultimate measure of RPA airdrop will be the increased effectiveness and efficiency of current airdrop missions and the development of new mission sets.

Major Farrell is a student at Advanced Study of Air Mobility. He is a senior pilot and has flown the C-17. His next assignment is at the Pentagon, Washington DC.

Quad Chart

Remotely Piloted Aircraft (RPA) Performing the Airdrop Mission

Maj Patrick F. Farrell
Advisor: Lt Col Joseph B. Skipper, PhD
Advanced Studies of Air Mobility (ENS)
Air Force Institute of Technology

Introduction

The US military currently has a gap in capability to rapidly resupply troops in contact as well as a lack of adequate capability to conduct airdrop operations in denied or contaminated airspace. Utilizing RPA for airdrop could eliminate both of these gaps. This research identified rapid and low-cost ways to implement RPA airdrop utilizing the MQ-9 Reaper through a joint and multi-functional panel participating in a Policy Delphi Study. The panel indicated that there are many current missions that RPA could support or perform more efficiently and/or effectively than manned aircraft as well as enabling the development of new mission sets which existing assets cannot support, such as rapid, precision resupply by persistent airborne assets. This study should serve as a baseline for policy development as the panel developed many capabilities, advantages, disadvantages and obstacles which should be considered before implementation.

Research Goals

- Analyze military and business literature to determine feasibility of repurposing RPA for airdrop
- Determine the airdrop capabilities of the MQ-9
- Determine the advantages of RPA airdrop
- Determine the disadvantages of RPA airdrop
- Determine the difficulties that need to be addressed early in order to successfully utilize the MQ-9 Reaper for airdrop

AIR FORCE INSTITUTE of TECHNOLOGY

General Framework

1. What are the airdrop roles and mission types that the MQ-9 Reaper could be utilized in without major structural changes to the aircraft?	Average Ranking
Imagery & PI coordinate updates in dynamic environment	2.33
Search & C2 in a Personnel Recovery (PR) with ability to re-supply the survivor(s)	3.11
Drop Zone Control Officer (DZCO), C2, & manned aircraft communications relay	4.0
DZ Wind Analysis	4.22
Airdrop of small items: i.e. ground sensors, robots, or Information Ops leaflets	4.67
Enable remote DZCO operation with no control personnel on the ground	4.89
Resupply of small units	6.11
Visual Guidance, Navigation & Control (GNC) for GPS denied airdrop	6.67

2. What are the advantages to be gained over current airdrop platforms, including new mission sets that could be created, by utilizing the MQ-9 Reaper for airdrop?	Average Ranking
Mitigate risk to manned aircraft in elevated threat environments	2.78
Airdrop of unattended ground sensors in real-time support of ISR missions	3.33
Wind Analysis to eliminate current need for multiple passes by manned aircraft	3.67
Provide persistent availability of emergency resupply on routine ISR missions	4.33
Nuclear, biological, chemical, radiological (NBCR) environment airdrop operations	4.67
Airdrop of Unmanned Ground Systems (UGSs) in elevated threat areas	5.0
24/7/365 alert to launch for emergency airdrop missions	5.44
Low-Cost, Low-Altitude airdrop	6.78

3. What are the unavoidable drawbacks of utilizing the MQ-9 Reaper for airdrop?	Average Ranking
Airdrop could compete unfavorably against other missions for the MQ-9	2.11
Limited payload	2.89
Maximum weapons load reduced if airdrop payloads utilized	3.67
Airdrop pods will reduce time on station for ISR missions due to weight & drag	4.11
Requires specially designed external pods to contain payload	5.11
Creates need for secure MQ-9 launch locations close to area of employment	5.22
Less flexibility than manned aircraft for dynamic changes	6.11
Execution delays at drop time due to satellite link delays	7.33
Cannot resupply units without a suitable DZ	8.22

4. What are the difficulties that need to be addressed early in prototyping, planning, procurement, or training in order to successfully utilize the MQ-9 Reaper for airdrop?	Average Ranking
Dedicated MQ-9s w/o ISR Processing, Exploitation & Dissemination (PED) tail	3.56
Development of JPADS capable pods & payloads to hang externally	3.67
Integration with other resupply platforms, ground stations & ground forces	3.89
Joint training to mitigate seams between MQ-9 operators, customers & support	4.11
Modifications to carry & deploy dropsondes for wind collection	4.89
Joint development team to ensure compatibility of interfaces	5.44
Tactics, Techniques and Procedures (TTP) & concept of employment development	6.33
Upgrade to allow automated airdrop execution with satellite signal loss	6.56
Display software updates to provide an airdrop damage hazard area overlay	7.56
Flight profiles & defensive systems to improve survivability at low altitudes	9.0

Panel Composition

Airdrop systems senior leader / engineer 20+ years airdrop & 10+ years RPA experience
MAJCOM RPA operations expert with 20+ years airdrop & 3 years RPA experience
JPADS senior project manager / engineer 20+ years airdrop & 5+ years RPA experience
MAJCOM intelligence expert with 15+ years intelligence & 5+ years RPA experience
Army logistics expert with 15+ years logistics experience at staff level
Medium RPA senior engineer with 10+ years in current position
MAJCOM airdrop operations expert with 10+ years airdrop experience
RPA instructor pilot with 1,200+ hours
MAJCOM RPA employment planner with 4 years RPA experience

Motivation

- Provide capabilities currently gapped, such as persistent , precision, on-call, emergency resupply; remote DZ C2; real-time remote wind analysis and imagery updates for manned airdrop missions; & persistent NBCR operations

Impacts/Contributions

- Increase UCCs' freedom of action by reducing risk, opening new battlespace and enabling new mission sets
- Increase effectiveness and efficiency of traditional airdrop operations

Collaboration

USAF AMC, ACC, AFSOC, AFMC
US Army Logistics Innovation Agency & Natick Soldier Research, Development & Engineering Center
Air Mobility Command AA9

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14. ABSTRACT
This research, sponsored by AMC/AA9, utilized a four round Policy Delphi Study to determine the potential utility, benefits, drawbacks and pitfalls of utilizing MQ-9 RPA to perform the airdrop mission. Literature concerning the MQ-9, RPAs, Joint Precision Aerial Delivery Systems, repurposing and rebranding, and Delphi Studies was reviewed. The panel's responses indicate that MQ-9 RPA capabilities should be developed both to support manned airdrop and to conduct small, especially persistent, resupply missions autonomously. RPA airdrop will greatly increase UCCs' freedom of action in elevated or denied threat areas, as well as NBCR environments, by removing the risk of loss of manned aircraft or harm to crews.

15. SUBJECT TERMS
Remotely Piloted Aircraft, RPA, airdrop, MQ-9, Joint Parachute Aerial Delivery System, JPADS, repurposing, rebranding, Delphi, TRANSCOM, AMC

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